Organization of tropical convection and relationship with extreme precipitation events

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1. Introduction

The re-distribution of heat and water by precipitation and clouds associated with the organization of tropical convection is arguably the most fundamental atmospheric processes affecting weather and climate. The organization of tropical convection influences not only the occurrence of extreme precipitation events (EPE) in the tropics, but also EPE's outside the tropics, through atmospheric teleconnection. In spite of advances in understanding gained from a large body of past research, the organization of tropical convection, in relationship to diabatic heating processes and EPEs remains one of most challenging problem in atmospheric processes and climate research. The unprecedented rich array of rainfall data products, and modeling tools supported by the Precipitation Measuring Mission that includes the TRMM and GPM satellite mission, offer a great opportunity for the scientific community to tackle this challenging problem. The objectives of the proposed research are to improve understanding of a) the organization of tropical convection, in terms of precipitation and cloud systems characteristics and relationships with extreme precipitation events (EPEs) in the tropics, and b) the contributions of organized convections through atmospheric teleconnection to occurrence and potential predictability of extratropical EPEs over the Pacific Northwest of the US.

2. Characteristics of MOTC

Objective : To better understand key processes and their interactions leading to the maximum organization of tropical convection (MOTC)

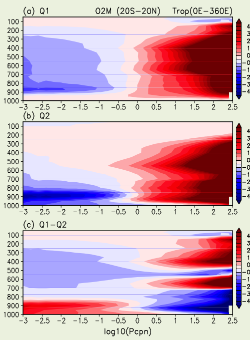


Figure 1. Exploring structural changes of diabatic heating (Q1) and moisture sink (Q2), and heating by radiative and convective updraft (Q1-Q2) for different convective types. (Shown as a function of rain intensity)

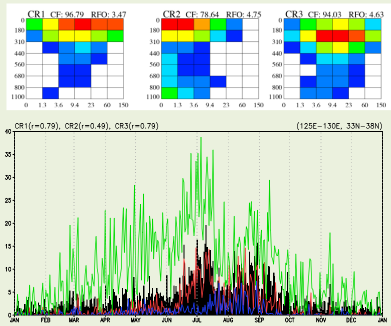
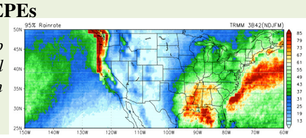


Figure 2. The cloud regime centroids as derived from k-means clustering analysis on the combined Aqua-Terra MODIS 1° joint histograms of cloud top pressure and cloud optical thickness (Courtesy of Lazaros Oraiopolous and N.-Y Cho). Bottom plots show the seasonal variation of the occurrences of cloud regimes over north-east Asia.

3. Relationship between MOTC and EPEs

Objective : To examine the relationship between MOTC and EPEs. Is there potential predictability of EPEs associated with MOTC?



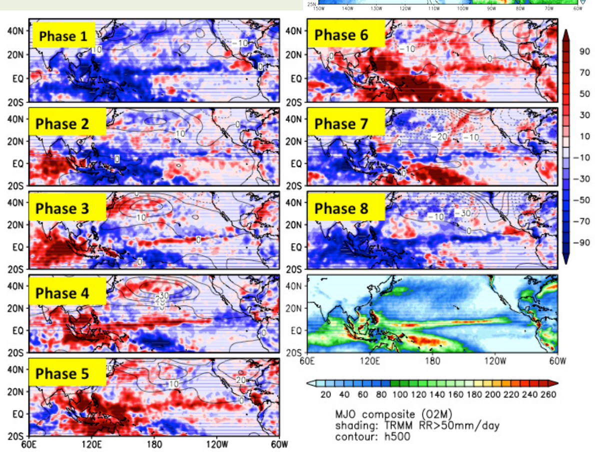


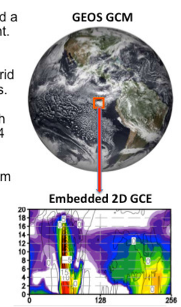
Figure 4. Frequency of occurrence of heavy rainfall events (>50mm/day) as a function of MJO phases.

4. Impact of cloud-radiation interaction: Goddard MMF Experiments

Objective: To examine the impacts of cloud-radiation interaction on MOTC and EPEs and teleconnection patterns, and to better understand the dynamics of MOTC and potential predictability of EPEs.

The Goddard Multiscale Modeling Framework (GMMF)

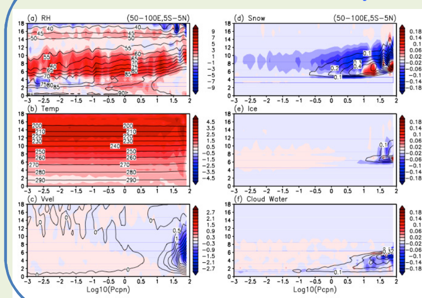
- The GMMF uses GEOS model as a host GCM and a 2D GCE model as the embedded CRM component.
- The moist parameterizations in GEOS GCM were replaced by a embedded 2D GCE at each GCM grid column to explicit simulate clouds and convections.
- The GEOS GCM has 2.0° X 2.5° grid spacing with 48 vertical layers stretching from the surface to 0.4 hPa.
- The 2D GCE has 32 x 44 (x-z) grid points with 4 km horizontal resolution and time step of 10 second.
- Globally there are more than 13,100 copies of 2D GCE running concurrently.
- The GMMF allows two-way interactions between cloud and large scale.



EXP	GCM resolution	GCE resolution	Period
Control	2.0°x2.5°	32 grid pts 4 km	Oct. 2011-Feb. 2012
NoCRF	2.0°x2.5°	32 grid pts 4 km	Oct. 2011-Feb. 2012

Table 1. Experiment Setup. Cloud-radiation interaction is turned off in NoCRF. Effect of cloud radiative feedback is defined as Control minus NoCRF.

Hydrometeor Profile



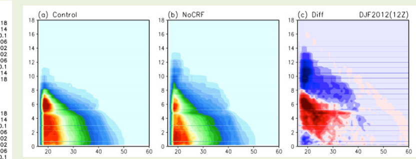


Figure 4 (left). Differences in frequency distribution of RH, temperature, vertical velocity (upward motion is positive), and hydrometeor profiles between Control and NoCRF as a function of rain rate.

Figure 5 (top). GMMF CFADs constructed from (a) Control, and (b) NoCRF experiment, and (c) difference between (a) and (b).

Mean (DJF)

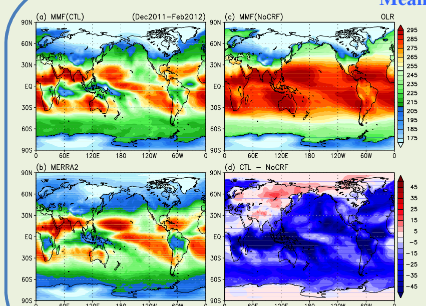


Figure 6. DJF mean OLR from (a) Control, (b) MERRA2, (c) NoCRF run, and (d) difference between Control and NoCRF.

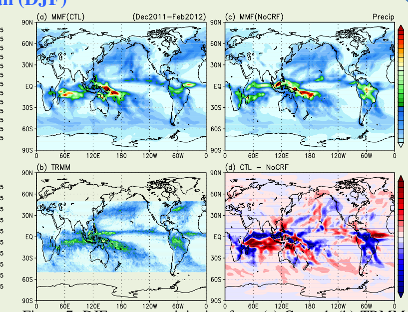


Figure 7. DJF mean precipitation from (a) Control, (b) TRMM, (c) NoCRF run, and (d) difference between Control and NoCRF.

Diurnal Variation of Rainfall

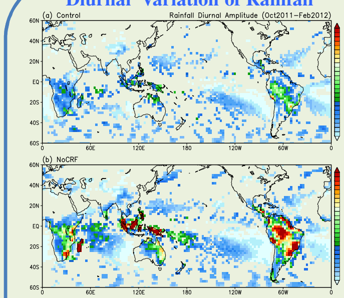


Figure 8. Amplitude of diurnal cycles of precipitation from (a) Control and (b) NoCRF run.

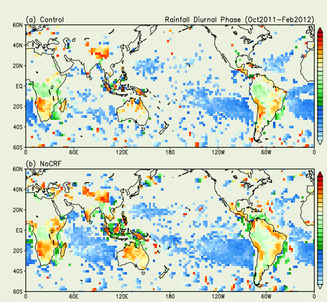


Figure 9. Diurnal phases of precipitation from (a) Control and (b) NoCRF run.

Diurnal Variation of Rainfall

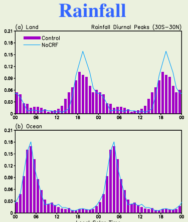


Figure 10. Frequency distribution of diurnal peaks over (a) land, and (b) ocean.

MJO

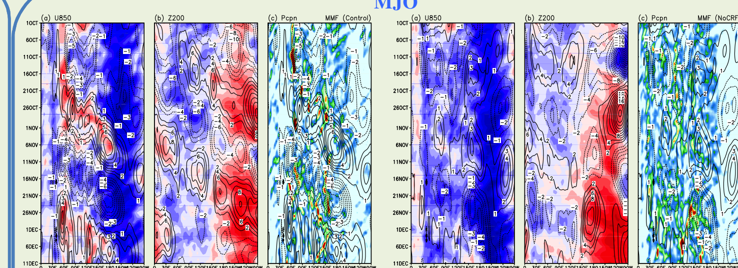


Figure 11. Time-longitude section of zonal winds at850hPa and 200hPa, and precipitation from Control (left panel) and NoCRF runs (right panel).

Summary

Impacts of cloud-radiation interactions on precipitation are examined by conducting two sets of five-month simulations using the Goddard MMF (GMMF), with (Control) and without (NoCRF) cloud-radiation feedback. Cloud effects are discussed based on the difference between Control and NoCRF experiments. Preliminary results show that:

- Cloud-radiation interaction warms mid- to upper-tropospheric temperature, and causes overall increase of atmospheric stability. As a results, more shallower convections are found in the Control, and more intense but fewer deep convections in NoCRF.
- Cloud-radiation interaction improves the simulation of seasonal mean precipitation distribution, suppressing a "double-ITCZ-like" model structure over Indian Ocean and equatorial western Pacific Ocean.
- Associated with overall increase of atmospheric stability due to cloud-radiation feedback, the amplitude of diurnal cycle of precipitation is slightly weakened over land, and the diurnal peaks appear more broader in Control than in NoCRF.
- The eastward propagation of the MJO-like winds and rainfall anomalies seem more organized with cloud-radiation interaction.

Extended integrations for longer periods will be conducted to further explore the details of the cloud-radiation-dynamics feedback processes.